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(54) **METHOD AND DEVICE FOR RECTIFYING IMAGE PHOTOGRAPHED BY FISH-EYE LENS**

VERFAHREN UND VORRICHTUNG ZUM ENTZERREN VON DURCH FISCHAUGENLINSE FOTOGRAFIERTEN BILDERN

PROCÉDÉ ET DISPOSITIF POUR RECTIFIER UNE IMAGE PHOTOGRAPHIÉE PAR UN OBJECTIF ULTRA-GRAND-ANGLE

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- **Pranali Dhane ET AL: "A Generic Non-linear Method for Fisheye Correction", International Journal of Computer Applications, vol. 51, no. 10, 1 August 2012 (2012-08-01), pages 58-65, XP055628101, DOI: 10.5120/8082-1483**

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Description

FIELD OF THE INVENTION

[0001] The present invention relates to a rectifying method and rectifying device, and especially for a method and device for rectifying an image photographed by a fish-eye lens.

BACKGROUND OF THE INVENTION

[0002] A panorama image is a 360-degree image by stitching images photographed by a fish-eye lens using professional drawing tools of panorama image(such as panatools). The fish-eye lens is a wide-angle lens. As a usual definition, a lens with a view angle up to 180-degree is called as a fish-eye lens. The existing images photographed by a fish-eye lens usually become distorted, therefore, a method and device for rectifying an image photographed by a fish-eye lens is needed to rectify an image photographed by a fish-eye lens, so as to form an image with higher precision and further form a panorama image with higher precision.

[0003] FIG.1 shows an imaging diagram of a fish-eye lens. As shown in FIG.1, the incident light finally images on the film after refraction through the lens, the light through the optical axis directly images on the center of the image without refraction. The incident light with an incident angle θ will image on the film along the dotted line if not refracted, with a distance r_{Ref} to the center of the film: $r_{Ref}=f\times\tan(\theta)$, wherein f is a distance between the focus of the lens and the film. In fact, the incident light with an incident angle θ will be refracted through lens, the refracted light will be mapped onto the film with a distance r_{Real} to the center of the film, a function relationship between r_{Real} and θ as $r_{Real}=F(\theta)$, and the function is called as a mapping curve of the lens. The mapping parameters of the lens can be obtained from the manufacturer.

[0004] Table 1 shows mapping parameters of a fish-eye lens from the manufacturer.

Table 1: Lens Mapping Parameters

θ	r_{Real}	r_{Ref}	$r_{Real\ fitting}$	Errors (%)
...	...	...	...	...
83.50000000	1.29173667	9.29066858	1.28731667	-0.342174999
84.00000000	1.29651734	10.0713161	1.292040736	-0.345279146
84.50000000	1.30124767	10.99333721	1.29671462	-0.34836181
85.00000000	1.30592748	12.09914443	1.301338125	-0.35142495
85.50000000	1.31055658	13.45000025	1.305911055	-0.354469621
86.00000000	1.31513483	15.13779832	1.310433216	-0.357500531
86.50000000	1.31966204	17.30694293	1.314904415	-0.360518435
87.00000000	1.32413805	20.19810781	1.319324461	-0.36352622
87.50000000	1.32856273	24.24450563	1.323693164	-0.366528868
88.00000000	1.33293591	30.31256159	1.328010336	-0.369528194
88.50000000	1.33725744	40.42393442	1.33227579	-0.372527367
89.00000000	1.34152721	60.64360003	1.336489341	-0.375532376
89.50000000	1.34574506	121.2964378	1.340650805	-0.37854532
90.50000000	1.35402452	-121.2964378	1.348816745	-0.384614522
91.00000000	1.35808589	-60.64360003	1.352820861	-0.387680119
91.50000000	1.36209488	-40.42393441	1.35677217	-0.390773801
92.00000000	1.36605137	-30.31256159	1.360670496	-0.393899828
92.50000000	1.36995528	-24.24450562	1.364515664	-0.397065219
93.00000000	1.3738065	-20.19810781	1.368307501	-0.400274638
93.50000000	1.37760495	-17.30694292	1.372045835	-0.403534768

(continued)

θ	r_{Real}	r_{Ref}	$r_{Real\ fitting}$	Errors (%)
94.00000000	1.38135055	-15.13779831	1.375730496	-0.40685212
94.50000000	1.38504322	-13.45000024	1.379361315	-0.410233042
95.00000000	1.3886829	-12.09914443	1.382938125	-0.413685154
...	...	...	...	...

[0005] Table 1 only shows the mapping parameters for some incident angles, while a complete table of the mapping parameter has a range of $[0, \frac{fov}{2}]$, including the mapping parameters every 0.5-degree incident angle; herein, fov is the lens field angle. Drawing scatter plot graphs according to the mapping parameter table, and then a fitting curve is obtained by linear regression. The fitting curve according to Table 1 is:

$$r_{Real} = F(\theta) = 1.0\times10^{-9}\theta^4 - 6.0\times10^{-7}\theta^3 + 8.5\times10^{-6}\theta^2 + 0.0183\theta + 0.0007 \quad \text{(Formula 1)}$$

by comparing the result calculated from the fitting curve with the real result, thus the Error:

$$Error = (r_{Real\ fitting} - r_{Real}) / r_{Real} \times 100\% \quad \text{(Formula 2).}$$

The Error of the fitting curve is less than 0.5%. Of course, the fitting curve of less error can be obtained by increasing the order of the polynomial.

[0006] Therefore, a method and device for rectifying an image photographed by a fish-eye lens is needed in the field for rectifying the images photographed by a fish-eye lens with an viewing angle over 180 degrees and with given parameters, so as to form an image with higher precision, and form a panorama image with higher precision by further stitching.

The document US 8482595B2 discloses an Methods of obtaining panoramic images using rotationally symmetric wide angle lenses according to the first two steps of claim 1 but not with steps of "acquiring centre coordinate and radius of a fish-eye circle in a fish-eye image; creating a blank image used for rectifying the image according to the lens field angle; based on the lens field angle, the fitted mapping curve, the centre coordinate and the radius of the fish-eye circle, and a width and height of the blank image, mapping a point on the blank image used for rectifying the image to a corresponding point in the fish-eye image; and based on a color sample of the corresponding point in the fish-eye image, drawing same onto the corresponding point in the blank image used for rectifying the image, and drawing the rectified image ".

Pranali Dhane ET AL: "A Generic Non-linear Method for Fisheye Correction", International Journal of Computer Applications, vol. 51, no. 10, 1 August 2012 (2012-08-01), pages 58-65, discloses a method for rectifying an image photographed by a fisheye lens.

SUMMARY OF THE INVENTION

[0007] An object of the present invention is to provide a method and device for rectifying an image photographed by a fish-eye lens, which can rectify an image photographed by a fish-eye lens to overcome the disadvantages in the existing technology. Specifically, the objections of the present invention can be obtained by the following rectifying method and device.

[0008] A method for rectifying an image photographed by a fish-eye lens in accordance with an embodiment of the present invention, comprises steps of

acquiring a fish-eye lens mapping parameter and a lens field angle;
acquiring a fitted mapping curve according to the lens mapping parameter;
acquiring centre coordinate and radius of a fish-eye circle in a fish-eye image;

creating a blank image used for rectifying the image according to the lens field angle;
based on the lens field angle, the fitted mapping curve, the centre coordinate and the radius of the fish-eye circle, and the width and height of the blank image, mapping a point on the blank image used for rectifying the image to a corresponding point in the fish-eye image; and
based on a color sample of the corresponding point in the fish-eye image, drawing same onto the corresponding point in the blank image used for rectifying the image, and drawing the rectified image, characterized in that, the step of acquiring a fitted mapping curve according to the lens mapping parameters specifically is: acquiring the fitted mapping curve by combining the lens mapping parameter with Formula 1, wherein θ is the incident angle, r_{Real} is a distance to a center of a film from where the light at the incident angle θ is mapped on the film after being refracted through a lens.

[0009] In the method for rectifying an image photographed by a fish-eye lens provided in accordance with the embodiment of the present invention, the step of acquiring centre coordinate and radius of a fish-eye circle in a fish-eye image specifically is: acquiring centre coordinate X_0 and Y_0 and the radius '*R*' of the fish-eye circle in a fish-eye image, wherein the fish-eye circle is the smallest circle capable of containing all the images in the fish-eye image.

[0010] In the method for rectifying an image photographed by a fish-eye lens provided in accordance with the embodiment of the present invention, the step of creating a blank image used for rectifying the image according to the lens field angle specifically is: setting a width W and a height h of the blank image according to a size of the image to be rectified, and that an aspect ratio (w:h) of the blank image used for rectifying the image is a fish-eye lens field angle fov: 180.

[0011] In the method for rectifying an image photographed by a fish-eye lens provided in accordance with the embodiment of the present invention, wherein the step of based on the lens field angle, the fitted mapping curve, the centre coordinate and the radius of the fish-eye circle, and the width and height of the blank image, mapping a point on the blank image used for rectifying the image to a corresponding point in the fish-eye image, further comprises steps of

step 5a: converting a coordinate (x, y) of a point on the blank image used for rectifying the image to a spherical coordinate (x_1, y_1, z_1) based on the latitude and longitude mapping method;
step 5b: forming a new space coordinate (x', y', z') by rotating the converted spherical coordinate (x_1, y_1, z_1) -90 degrees about the Y axis of the space coordinate; and
step 5c: obtaining the coordinate (u, v) mapped in the fish-eye image based on the new space coordinate.

[0012] In the method for rectifying an image photographed by a fish-eye lens provided in accordance with the embodiment of the present invention, and in the above step 5a: an incident angle θ and a deviation angle φ can be calculated based on the coordinate (x, y) of a point on the blank image used for rectifying the image, the fish-eye lens field angle fov, and Formula 3 and Formula 4 described below; and the spherical coordinate (x_1, y_1, z_1) can be calculated based on the angles θ and φ used in Formulas 5-7 described below.

[0013] In the method for rectifying an image photographed by a fish-eye lens provided in accordance with the embodiment of the present invention, and in the above step 5b, the space coordinate (x', y', z') can be obtained based on the converted spherical coordinate (x_1, y_1, z_1) and Formula 8 described below.

[0014] In the method for rectifying an image photographed by a fish-eye lens provided in accordance with the embodiment of the present invention, and in the above step 5c, a converted incident angle θ' and a converted deviation angle φ' can be calculated based on Formulas 9-10 described below and the space coordinate (x', y', z'); the radius *'radius'* can be calculated based on the angle θ', Formula 1, the lens field angle fov, and Formula 11 described below; and the coordinate (u, v) mapped in the fish-eye image can be calculated based on the angle φ', the center coordinates x_0 and y_0 of the fish-eye circle, the radius *'radius'*, and Formula 12 and Formula 13 described below.

[0015] A device for rectifying an image photographed by a fish-eye lens provided in accordance with another embodiment of the present invention, wherein, comprises:

a first data acquisition unit, used for acquiring a fish-eye lens mapping parameter and a lens field angle;
a mapping curve fitting unit, used for acquiring a fitted mapping curve according to the lens mapping parameter;
a second data acquisition unit, used for acquiring a centre coordinate and radius of a fish-eye circle in a fish-eye image;
a blank image creation unit, used for creating a blank image used for rectifying the image according to the lens field angle;
a mapping unit, used for based on the lens field angle, the fitted mapping curve, the centre coordinate and the radius of the fish-eye circle, and the width and height of the blank image, mapping a point on the blank image used for rectifying the image to a corresponding point in the fish-eye image; and
a drawing unit, used for based on a color sample of the corresponding point in the fish-eye image, drawing same onto the corresponding point in the blank image used for rectifying the image, and drawing the rectified image;
characterized in that the device acquires a fitted mapping curve according to the lens mapping parameter by com-

bining the acquired mapping parameter with Formula 1:

$$r_{Real} = F(\theta) = 1.0\times10^{-9}\theta^4 - 6.0\times10^{-7}\theta^3 + 8.5\times10^{-6}\theta^2 + 0.01830\theta + 0.0007$$

wherein θ is the incident angle, and r_{Real} is a distance to a center of a film from where the light at the incident angle θ is mapped on the film after refracted through a lens;
the device acquires the centre coordinate X_0 and Y_0 and the radius *'R'* of the fish-eye circle in a fish-eye image; and the fish-eye circle is the smallest circle capable of containing all the images in the fish-eye image;
the device sets the width W and the height h of the blank image according to a size of the image to be rectified; and an aspect ratio of the blank image used for rectifying the image is a fish-eye lens field angle fov: 180, where fov is a fish-eye lens field angle.

[0016] In the device for rectifying an image photographed by a fish-eye lens in accordance with another embodiment of the present invention, the mapping unit further comprises units of:

a first conversion unit, used for converting a coordinate (x, y) of a point on the blank image used for rectifying the image to a spherical coordinate (x_1, y_1, z_1) based on the latitude and longitude mapping method;
a second conversion unit, used for forming a new space coordinate (x', y', z') by rotating the converted spherical coordinate (x_1, y_1, z_1) -90 degrees about the Y axis of the space coordinate; and
a third conversion unit, used for obtaining the coordinate (u, v) mapped in the fish-eye image based on the new space coordinate.

[0017] In the device for rectifying an image photographed by a fish-eye lens in accordance with another embodiment of the present invention, the first conversion unit calculates the incident angle θ and the deviation angle φ based on the coordinates x and y of a point on the blank image used for rectifying the image, the fish-eye lens field angle fov, the width W and the height h of the blank image, and Formula 3 and Formula 4; and calculates the spherical coordinate (x_1, y_1, z_1) based on the angles θ and φ used in Formula 5, Formula 6 and Formula 7.

[0018] In the device for rectifying an image photographed by a fish-eye lens in accordance with another embodiment of the present invention, the second conversion unit acquires the space coordinates x', y' and z' based on the converted spherical coordinate x_1, y_1 and z_1 and Formula 8.

[0019] In the device for rectifying an image photographed by a fish-eye lens in accordance with another embodiment of the present invention, the third conversion unit calculates a converted incident angle θ' and a converted deviation angle φ' based on Formulas 9-10 described below and the space coordinate (x', y', z'); and calculates the radius *'radius'* based on the angle θ', Formula 1, the lens field angle fov, and Formula 11; and calculates the coordinate (u, v) mapped in the fish-eye image based on the angle φ', the center coordinates x_0 and y_0 of the fish-eye circle, the radius *'radius'*, and Formula 12 and Formula 13.

[0020] Another object of the invention is a computer program product comprising instructions which, when the program is executed by a computer, cause the computer to carry out the above-mentioned method.

[0021] The method and device for rectifying an image photographed by a fish-eye lens of the present invention can rectify the distorted images photographed by a fish-eye lens, so as to form an image with higher precision, and further to form a panorama image with higher precision by stitching the rectified images.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022]

FIG.1 illustrates an imaging diagram of a fish-eye lens.
FIG.2 illustrates a flow chart of a method for rectifying an image photographed by a fish-eye lens in accordance with an embodiment of the present invention.
FIG.3 illustrates the method for rectifying an image photographed by a fish-eye lens in accordance with an embodiment of the present invention.
FIG.4 illustrates a blank image used for rectifying an image of FIG. 2.
FIG.5 illustrates a schematic diagram of the coordinate of a point in the blank image for rectifying an image of FIG.4 converted to the spherical coordinate.
FIG.6 illustrates a deviation angle, radius 'R' and *'radius'.*
FIG.7 illustrates a device for rectifying an image photographed by a fish-eye lens in accordance with another embodiment of the present invention.

FIG.8 illustrates a schematic diagram of the device for rectifying an image photographed by a fish-eye lens in accordance with an embodiment of the present invention.

FIG.9 schematically illustrates a program product.

DETAILED DESCRIPTION OF EMBODIMENTS

[0023] FIG.1-9 and the following description illustrate the optional embodiments of the present invention so as to teach the skilled in the art how to implement and recover the present invention. For teaching the technical solution of the present invention, some common aspects have been simplified. The skilled in the art can understand that variations or modifications made to the equivalent, should be covered within the scope of the present invention. It is understood that the following characters can become a variety of forms of the present invention by various combinations. Thereby, the present invention is not limited to the following optional embodiments. The scope of the present invention is defined by the appended claims and equivalents thereof.

[0024] FIG.6 illustrates a deviation angle, the radius 'R' and the radius *'radius'.* The images on the film and the fish-eye images have an equal scale, a unit of the image on the film is mm, and the radius of the fish-eye image is pixel. The point imaged on the film of the light at the incident angle θ, accordingly forms a circle C_1 in the fish-eye image with a center $O_c(x_0,y_0)$ and the radius *'radius'.* When θ=fov/2, that is, the light enters at the maximum incident angle, the circle imaged on the film corresponds to the circle in the fish-eye image with a center $O_c(x_0,y_0)$ and the radius *'R'.* The deviation angle φ is a deviation angle that the point imaged on the film of the light at the incident angle θ corresponds to C_1 in the fish-eye image, and a range of φ is [0, 360].

Exemplary method

[0025] FIG.2 and FIG.3 together illustrate a method for rectifying an image photographed by a fish-eye lens as an embodiment of the present invention. FIG.2 illustrates a flow chart of a method for rectifying an image photographed by a fish-eye lens in accordance with an embodiment of the present invention. FIG.3 illustrates an embodiment of the present invention of the method for rectifying an image photographed by a fish-eye lens. As shown in FIG.2 and FIG.3, a method for rectifying an image photographed by a fish-eye lens comprises steps of:

step 100: start of a method for rectifying an image photographed by a fish-eye lens in accordance with an embodiment of the present invention;
step 110: acquiring a fish-eye lens mapping parameter and a lens field angle;
step 120: acquiring a fitted mapping curve according to the lens mapping parameter;
step 130: acquiring centre coordinate and radius of a fish-eye circle in a fish-eye image;
step 140: creating a blank image for rectifying an image;
step 150: based on the lens field angle, the fitted mapping curve, the centre coordinate and the radius of the fish-eye circle, and a width and a height of the blank image, mapping a point on the blank image used for rectifying the image to a corresponding point in the fish-eye image;
step 160: based on a color sample of the corresponding point in the fish-eye image, drawing same onto the corresponding point in the blank image used for rectifying the image, and drawing the rectified image; and
step 170: end of the method for rectifying an image photographed by a fish-eye lens in accordance with an embodiment of the present invention.

[0026] In the step 110, the fish-eye lens mapping parameter and the lens field angle can be obtained from the manufacturer of the fish-eye lens.

[0027] The step 120, acquiring a fitted mapping curve according to the lens mapping parameter, is that: acquiring the fitted mapping curve by combining the lens mapping parameter with Formula 1.

[0028] In the step 130, the center (X_0, Y_0) and the radius 'R' of the fish-eye circle in the fish-eye image are determined, wherein the fish-eye circle is the smallest circle capable of containing all the images in the fish-eye image.

[0029] In the step 140, a width W and a height h of the blank image are set according to a size of the image to be rectified, and an aspect ratio of the blank image used for rectifying the image is fov: 180.

[0030] The step 150, based on the lens field angle, the fitted mapping curve, the centre coordinate and the radius of the fish-eye circle, and the width and height of the blank image, mapping a point on the blank image used for rectifying the image to a corresponding point in the fish-eye image, further comprises steps of:

step 150a: converting a coordinate (x, y) of a point on the blank image used for rectifying the image to a spherical coordinate (x_1, y_1, z_1) based on the latitude and longitude mapping method;
step 150b: forming a new space coordinate (x', y', z') by rotating the converted spherical coordinate (x_1, y_1, z_1) -90

degrees about the Y axis of the space coordinate; and

step 150c: obtaining the coordinate (u, v) mapped in the fish-eye image based on the new space coordinate.

[0031] Specifically, FIG.5 illustrates the coordinate of a point on the blank image used for rectifying the image of FIG.4 to be converted to the spherical coordinate. In the step 150a, the incident angle θ and the deviation angle φ can be calculated based on the coordinates (x, y) of a point on the blank image used for rectifying the image, the fish-eye lens field angle fov, and the width W and the height h of the blank image, (for example using Formula 3 and Formula 4); and the spherical coordinatex_1, y_1, and z_1 can be calculated based on Formulas 5-7 and the incident angle θ, the deviation angle φ.

$$\theta = y / h \times \pi \qquad \text{(Formula 3)};$$

$$\varphi = (x / w \times fov + (360 - fov) / 2) \times \pi/180 \qquad \text{(Formula 4)};$$

$$x_1 = \sin(\theta)\cos(\varphi) \qquad \text{(Formula 5)};$$

$$y_1 = \sin(\theta)\sin(\varphi) \qquad \text{(Formula 6)};$$

$$z_1 = \cos(\theta) \qquad \text{(Formula 7)}.$$

[0032] Specifically, in the 150b, the space coordinates x', y' and z' are obtained based on the converted spherical coordinates x_1, y_1 and z_1 and Formula 8:

$$[x', y', z', 1] = [x_1, y_1, z_1, 1]\begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \\ -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \qquad \text{(Formula 8)}$$

[0033] Specifically, FIG.4 illustrates a created blank image used for rectifying the image of FIG.2. In the step 150c, a converted incident angle θ' and a converted deviation angle φ' can be calculated based on Formulas 9 and 10 and the space coordinates (x', y', z'). The radius *'radius'* can be calculated based on the converted incident angle θ', Formula 1, the lens field angle fov, and Formula 11; and the coordinate (u, v) mapped in the fish-eye image can be calculated based on the angle φ', the center coordinates x_0 and y_0 of the fish-eye circle, the radius *'radius',* and Formula 12 and Formula 13.

$$\theta' = \mathrm{atan}(\sqrt{x'^2 + y'^2}, z')/\pi \times 180 \qquad \text{(Formula 9)}$$

$$\varphi' = \mathrm{atan}(y', x') \qquad \text{(Formula 10)}$$

$$radius = R \times F(\theta') / F(fov / 2) \qquad \text{(Formula 11)}$$

$$u = radius \times \cos(\varphi') + x_0 \qquad \text{(Formula 12)}$$

$$v = radius \times \sin(\varphi') + y_0 \qquad \text{(Formula 13)}$$

Exemplary Device

[0034] The above description combined with FIG. 2-3 discloses the method for rectifying an image photographed by a fish-eye lens in accordance with the embodiment of the present invention. The following will combine FIG.7 to describe a device for rectifying an image photographed by a fish-eye lens in accordance with the embodiment of the present invention. FIG.7 illustrates another embodiment of the present invention of the device for rectifying an image photographed by a fish-eye lens. The device 1 comprises:

a first data acquisition unit 2, used for acquiring a fish-eye lens mapping parameter and a lens field angle ;
a mapping curve fitting unit 3, used for acquiring a fitted mapping curve according to the lens mapping parameter;
a second data acquisition unit 4, used for acquiring centre coordinate and radius of a fish-eye circle in a fish-eye image;
a blank image creation unit 5, used for creating a blank image used for rectifying the image according to the lens field angle;
a mapping unit 6: used for mapping a point on the blank image used for rectifying the image to a corresponding point in the fish-eye image based on the lens field angle, the fitted mapping curve, the centre coordinate and the radius of the fish-eye circle, and the width and height of the blank image; and
a drawing unit 7: used for drawing same onto the corresponding point in the blank image used for rectifying the image, and drawing the rectified image based on a color sample of the corresponding point in the fish-eye image.

[0035] The device for rectifying an image photographed by a fish-eye lens in accordance with another embodiment of the present invention, acquires the fitted mapping curve according to the lens mapping parameter using the acquired mapping parameters combined with Formula 1; wherein θ is the incident angle, r_{Real} is a distance to a center of a film from where the light at the incident angle θ is mapped on the film after refracted through a lens.

[0036] The device for rectifying an image photographed by a fish-eye lens in accordance with another embodiment of the present invention, acquires the centre coordinate X_0 and Y_0 and the radius *'R'* of the fish-eye circle in a fish-eye image, wherein the fish-eye circle is the smallest circle capable of containing all the images in the fish-eye image.

[0037] In the device for rectifying an image photographed by a fish-eye lens in accordance with another embodiment of the present invention, a width W and a height h of the blank image are set according to a size of the image to be rectified, and an aspect ratio of the blank image used for rectifying the image is a fish-eye lens field angle fov: 180.

[0038] In the device for rectifying an image photographed by a fish-eye lens in accordance with another embodiment of the present invention, the mapping unit further comprises the following conversion units of:

a first conversion unit, used for converting a coordinate (x, y) of a point on the blank image used for rectifying the image to a spherical coordinate (x_1, y_1, z_1) based on the latitude and longitude mapping method;
a second conversion unit, used for forming a new space coordinate (x', y', z') by rotating the converted spherical coordinate (x_1, y_1, z_1) -90 degrees about the Y axis of the space coordinate; and
a third conversion unit, used for obtaining the coordinate (u, v) mapped in the fish-eye image based on the new space coordinate.

[0039] In the device for rectifying an image photographed by a fish-eye lens in accordance with another embodiment of the present invention, the first conversion unit calculates the incident angle θ and the deviation angle φ based on the coordinates x and y of a point on the blank image used for rectifying the image, the fish-eye lens field angle fov, the width W and the height h of the blank image, and Formula 3 and Formula 4; and calculates the spherical coordinate (x_1, y_1, z_1) based on the angles θ and φ used in Formula 5, Formula 6 and Formula 7.

[0040] In the device for rectifying an image photographed by a fish-eye lens in accordance with another embodiment of the present invention, the second conversion unit acquires the space coordinates x', y' and z' based on the converted spherical coordinate x_1, y_1 and z_1 and Formula 8.

[0041] In the device for rectifying an image photographed by a fish-eye lens in accordance with another embodiment of the present invention, the third conversion unit calculates a converted incident angle θ' and a converted deviation angle φ' based on Formula 9 and Formula 10 and the space coordinates x', y', and z'; and calculates the radius *'radius'* based on the angle θ', Formula 1, the lens field angle fov, and Formula 11; and calculates the coordinates u and v mapped in the fish-eye image based on the angle φ', the center coordinates x_0 and y_0 of the fish-eye circle, the radius *'radius',* and Formula 12 and Formula 13.

[0042] The method and device for rectifying an image photographed by a fish-eye lens of the present invention can rectify the distorted images photographed by the fish-eye lens, so as to form an image with higher precision, and further form a panorama image with higher precision by stitching the rectified images.

Exemplary Device

[0043] After the exemplary embodiment of the method and device of the present invention, then, another exemplary embodiment of the device for rectifying an image photographed by a fish-eye lens of the present invention will be described.

[0044] The skilled in the art can understood that, the various aspects of the present invention can be realized as a system, method or program product. Therefore, the various aspects of the present invention can be implemented in the forms of: embodiments of full hardware, embodiments of full software (including firmware and microcode), or embodiments of hardware combined with software, and these can be referred to as 'circuit', 'unit' or 'system'.

[0045] In some embodiments, the device for rectifying an image photographed by a fish-eye lens in the present invention, can further at least comprise at least one processing unit, and at least one memory unit. The memory unit is stored with program codes, when all the program codes are executed by the processing unit, the processing unit will execute the steps of the method in accordance with the various exemplary embodiments of the present invention as described above in "Exemplary method". For example, the processing unit can execute steps of FIG. 2:

step 110: acquiring a fish-eye lens mapping parameter and a lens field angle;
step 120: acquiring a fitted mapping curve according to the lens mapping parameter;
step 130: acquiring centre coordinate and radius of a fish-eye circle in a fish-eye image;
step 140: creating a blank image for rectifying an image;
step 150: based on the lens field angle, the fitted mapping curve, the centre coordinate and the radius of the fish-eye circle, and the width and height of the blank image, mapping a point on the blank image used for rectifying the image to a corresponding point in the fish-eye image; and
step 160: based on a color sample of the corresponding point in the fish-eye image, drawing same onto the corresponding point in the blank image used for rectifying the image, and drawing the rectified image.

[0046] The device 10 for rectifying an image photographed by a fish-eye lens in accordance with the embodiment of the present invention is described with reference to FIG.8. The device 10 for rectifying an image photographed by a fish-eye lens as shown in FIG. 8 is just an example, will not limit the functions and applications of the embodiments in the present invention.

[0047] As shown in FIG.8, the device 10 for rectifying an image photographed by a fish-eye lens is an universal computing device. The device 10 for rectifying an image photographed by a fish-eye lens comprises such components but not limited to: the at least one processing unit 16, the at least one memory unit 28, and a main Bus 18 for connecting different components (including the memory unit 28 and the processing unit 16) of the system.

[0048] Bus 18 is one or more of several Bus structures, and comprises memory Bus or memory controller, peripheral Bus, Accelerated Graphics Port, processor, or Locus Bus of any of various Bus structures.

[0049] The memory unit 28 may comprises a readable medium in a form of volatile memory, such as random access memory (RAM) 30 and/or Cache memory 32, and can further comprises Read-Only Memory (ROM) 34.

[0050] The memory unit 28 can further comprises programs/utilities 40 with a sets of (at least one) program units 42 thereof. Such program units 42 can comprise but not limited to: operation system, one or more application programs, other program units and program data. Each or some combination of these examples may include implementation based on network environment.

[0051] The device 10 for rectifying an image photographed by a fish-eye lens can also communicate with one or more external equipments (such as keyboards, pointing devices, Bluetooth devices, etc.), and also communicate with one or more user interaction devices to the device 10 for rectifying an image photographed by a fish-eye lens, and/or communicate with any other devices (such as router, modem etc.) which enables the device 10 for rectifying an image photographed by a fish-eye lens to communicates with one or more other computing devices. Such communication can be carried out through input/output (I/O) interface 22. Further, the device 10 for rectifying an image photographed by a fish-eye lens can communicate with one or more networks (e.g. local area networks (LAN), wide area networks (WAN) and/or public networks, such as the Internet) through a network adapter 20. As shown in the figures, the network adapter 20 communicates with other units of the device 10 for rectifying an image photographed by a fish-eye lens through the Bus 18. It is understood that, although not shown in the figures, the device 10 for rectifying an image photographed by a fish-eye lens can be combined with other hardware or software units, comprising but not limited: microcode, device driver, redundant processing unit, external disk drive arrays, RAID system, tape drives, and data backup storage system.

Exemplary program products

[0052] In some embodiment, the aspects of the present invention can also be implemented as a form of program product, comprising program codes. When the program product runs on a terminal device, the program codes are used for the terminal device to execute the steps of the method in accordance with the various exemplary embodiments of the present invention as described above in "Exemplary method". For example, the terminal can executes as shown in FIG. 2:

the step 110: acquiring a fish-eye lens mapping parameter and a lens field angle;
step 120: acquiring a fitted mapping curve according to the lens mapping parameter;
step 130: acquiring centre coordinate and radius of a fish-eye circle in a fish-eye image;
step 140: creating a blank image for rectifying an image;
step 150: based on the lens field angle, the fitted mapping curve, the centre coordinate and the radius of the fish-eye circle, and the width and height of the blank image, mapping a point on the blank image used for rectifying the image to a corresponding point in the fish-eye image; and
step 160: based on a color sample of the corresponding point in the fish-eye image, drawing same onto the corresponding point in the blank image used for rectifying the image, and drawing the rectified image.

[0053] The program product can use one or any combination of multiple readable medium. The readable medium can be a readable signal medium or a readable storage medium. The readable storage medium can be, for example, but not limited to, electrical, magnetic, optical, electromagnetic, infrared, or semiconductor systems, devices, or apparatus; or any combination thereof. The readable storage medium, as more specific examples (non-exhaustive list), comprises: an electric connection with one or more wires, portable disk, hard disk, Random Access Memory (RAM), Read-Only Memory (ROM), Erasable Programmable Read-Only Memory(EPROM or flash memory), optical fiber, Portable Compact Disk Read-Only Memory (CD-ROM), Optical memory devices, magnetic memory devices, or any applicable combination thereof.

[0054] As shown in FIG. 9, the program product 50 in accordance with an embodiment of the present invention, can use the Portable Compact Disk Read-Only Memory (CD-ROM) containing program codes, and can run on the terminal device such as a personal computer. But the program product of the present invention is not limited to this. In the present invention, the readable storage medium can be any physical medium containing or stored program, the program can be executed or combined in use by an instruction performed system, device or apparatus.

[0055] The readable signal medium can comprises data signal propagated in a baseband or as a part of the carrier wave, in which carries readable program code. The data signal in such propagation way can take a variety of forms, comprising but not limited to: electromagnetic signal, optical signal or any suitable combination thereof. The readable signal medium can also be any readable medium other than a readable storage medium. The readable medium can send, propagate, or transmit such program to the instruction performed system, device, or apparatus for use.

[0056] The program code carried in the readable medium can be transmitted via any suitable medium, comprising but not limited to: wireless, wired, optical cable, RF, etc., or any appropriate combination thereof.

[0057] The program code executed in the present invention can be written in one or any combination of more programming languages. Such programming languages comprises Object Oriented Program language, such as Java, C++ etc.; and also comprise common procedural programming language, such as "C" or the like. The program code can be completely executed on the user computing device, partly executed on the user equipment, executed as an independent software package, executed partly on the user computing device and partly on the remote computing device, or completely executed on the remote computing device or server. As for the situation of the remote computing device, the remote computing device can be connected to the user computing device via any network, comprising Local Area Network (LAN) or Wide Area Network (WAN); or, can be connected to the external computing device (e.g. via internet provided from the internet service providers).

[0058] It should be noted that, although the above describe the device or sub-device for rectifying an image photographed by a fish-eye lens in detail, such division is not compulsory. Actually, according to the embodiments of the present invention, the features and functions of two or more devices described above can be embodied in one device. And vice versa the characteristics and functions of one device described above can be further divided into multiple devices.

[0059] Additionally, the steps of the method of the present invention are illustrated in a particular order in the drawings, however, it is not required or indicated that these steps must be performed in the particular order, or must be completely performed to achieve the desired result.. Additionally or alternatively, some steps can be omitted, multiple steps can be merged into one step, and/or one step can be divided into multiple steps.

[0060] Although the principles of the present invention have been described in several embodiments, it is understood, the present invention should not be limited to the described embodiments, nor does the division of the various aspects mean that the features in these aspects cannot be combined to benefit, and such division is only for the convenience of expression. The scope of the invention is defined by the appended claims.

Claims

1. A method for rectifying an image photographed by a fish-eye lens, comprising steps of:

acquiring (110) a fish-eye lens mapping parameter and a lens field angle;
acquiring (120) a fitted mapping curve according to the lens mapping parameter;
acquiring (130) centre coordinate and radius of a fish-eye circle in a fish-eye image;
creating (140) a blank image used for rectifying the image according to the lens field angle;
based (150) on the lens field angle, the fitted mapping curve, the centre coordinate and the radius of the fish-eye circle, and a width and height of the blank image, mapping a point on the blank image used for rectifying the image to a corresponding point in the fish-eye image; and
based (160) on a color sample of the corresponding point in the fish-eye image, drawing same onto the corresponding point in the blank image used for rectifying the image, and drawing the rectified image;
characterized in that, in the step of acquiring (120) a fitted mapping curve according to lens mapping parameters, the fitted mapping curve is as Formula 1:

$$r_{Real} = F(\theta) = 1.0\times10^{-9}\theta^4 - 6.0\times10^{-7}\theta^3 + 8.5\times10^{-6}\theta^2 + 0.0183\theta + 0.0007,$$

wherein θ is an incident angle, r_{Real} is a distance to a center of a film from where the light at the incident angle θ is mapped on the film after refracted through a lens.

2. The method for rectifying an image photographed by a fish-eye lens of claim 1, wherein in the step of acquiring (130) centre coordinate and radius of a fish-eye circle in a fish-eye image: the centre coordinate X_0 and Y_0 and the radius 'R' of the fish-eye circle in a fish-eye image are acquired, wherein the fish-eye circle is the smallest circle capable of containing all images in the fish-eye image.

3. The method for rectifying an image photographed by a fish-eye lens of claim 1, wherein in the step of creating (140) a blank image used for rectifying the image according to the lens field angle:
the width w and the height h of the blank image are set according to a size of the image to be rectified, and an aspect ratio of the blank image is equal to fov: 180, where fov is a fish-eye lens field angle.

4. The method for rectifying an image photographed by a fish-eye lens of claim 1, wherein in the step of based (150) on the lens field angle, the fitted mapping curve, the centre coordinate and the radius of the fish-eye circle, and the width and height of the blank image, mapping a point on the blank image used for rectifying the image to a corresponding point in the fish-eye image, further comprises steps of

converting (5a) a coordinate (x, y) of a point on the blank image used for rectifying the image to a spherical coordinate (x_1, y_1, z_1) based on the latitude and longitude mapping method;
forming (5b) a new space coordinate (x', y', z') by rotating the converted spherical coordinate (x_1, y_1, z_1) -90 degrees about Y axis of the space coordinate; and
obtaining (5c) a coordinate (u, v) mapped in the fish-eye image based on the new space coordinate.

5. The method for rectifying an image photographed by a fish-eye lens of claim 4, wherein in the step of converting (5a) a coordinate (x,y) of a point on the blank image used for rectifying the image to a spherical coordinate (x_1, y_1, z_1) based on latitude and longitude mapping method, an incident angle θ and a deviation angle φ are calculated based on the coordinates x and y of a point on the blank image used for rectifying the image, the fish-eye lens field angle fov, the width w and the height h of the blank image, Formula 3: $\theta = y / h \times \pi$, and

$$\text{Formula 4: } \varphi = (x / w \times fov + (360 - fov) / 2) \times \pi/180;$$

the spherical coordinate (x_1, y_1, z_1) is calculated based on the incident angle θ, the deviation angle φ, Formula 5: $x_1 = \sin(\theta)\cos(\varphi)$,

$$\text{Formula 6: } y_1 = \sin(\theta)\sin(\varphi),$$

and

$$\text{Formula 7: } z_1 = \cos(\theta) \ .$$

6. The method for rectifying an image photographed by a fish-eye lens of claim 4, wherein in the step of forming (5b) a new space coordinate (x', y', z') by rotating the converted spherical coordinate (x_1, y_1, z1) -90 degrees about Y axis of the space coordinate, the space coordinates x', y' and z' are obtained based on the converted spherical coordinates x_1, y_1 and z_1 and Formula 8:

$$[x', y', z', 1] = [x_1, y_1, z_1, 1]\begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \\ -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \ .$$

7. The method for rectifying an image photographed by a fish-eye lens of claim 6, wherein in the step of obtaining (5c) a coordinate (u, v) mapped in the fish-eye image based on the new space coordinate, a converted incident angle θ' and a converted deviation angle φ' are calculated based on

$$\text{Formula 9: } \theta' = \operatorname{atan}(\sqrt{x'^2 + y'^2}, z')/\pi \times 180,$$

$$\text{Formula 10: } \varphi' = \operatorname{atan}(y', x')$$

and the space coordinates (x', y', z');

a radius *'radius'* is calculated based on the converted incident angle θ', Formula 1, the lens field angle fov, and Formula 11:

$$radius = R \times F(\theta') / F(fov / 2).$$

the coordinates u and v mapped in the fish-eye image are calculated based on the angle φ', the center coordinates x_0 and y_0 of the fish-eye circle, the radius *'radius'*,

$$\text{Formula 12: } u = radius \times \cos(\varphi') + x_0,$$

and

$$\text{Formula 13: } v = radius \times \sin(\varphi') + y_0 \ .$$

8. A device for rectifying an image photographed by a fish-eye lens, comprising:

a first data acquisition unit, used for acquiring a fish-eye lens mapping parameter and a lens field angle;
a mapping curve fitting unit, used for acquiring a fitted mapping curve according to the lens mapping parameter;
a second data acquisition unit, used for acquiring centre coordinate and radius of a fish-eye circle in a fish-eye image;
a blank image creation unit, used for creating a blank image used for rectifying the image according to the lens field angle;
a mapping unit, used for based on the lens field angle, the fitted mapping curve, the centre coordinate and the radius of the fish-eye circle, and a width and height of the blank image, mapping a point on the blank image used for rectifying the image to a corresponding point in the fish-eye image; and
a drawing unit, used for based on a color sample of the corresponding point in the fish-eye image, drawing

same onto the corresponding point in the blank image used for rectifying the image, and drawing the rectified image;
characterized in that, the fitted mapping curve is acquired according to lens mapping parameters as Formula 1:

$$r_{Real} = F(\theta) = 1.0\times10^{-9}\theta^4 - 6.0\times10^{-7}\theta^3 + 8.5\times10^{-6}\theta^2 + 0.0183\theta + 0.0007,$$

wherein θ is an incident angle, r_{Real} is a distance to a center of a film from where the light at the incident angle θ is mapped on the film after refracted through a lens;
the centre coordinate X_0 and Y_0 and the radius 'R' of the fish-eye circle in a fish-eye image are acquired, wherein the fish-eye circle is the smallest circle capable of containing all images in the fish-eye image;
the width w and the height h of the blank image are set according to a size of the image to be rectified, and an aspect ratio of the blank image is equal to fov: 180, where fov is a fish-eye lens field angle.

9. The device of claim 8, wherein a mapping unit comprises units of

a first conversion unit, used for converting a coordinate (x, y) of a point on the blank image used for rectifying the image to a spherical coordinate (x_1, y_1, z_1) based on the latitude and longitude mapping method;
a second conversion unit, used for forming a new space coordinate (x', y', z') by rotating the converted spherical coordinate (x_1, y_1, z_1) -90 degrees about Y axis of the space coordinate; and
a third conversion unit, used for obtaining a coordinate (u, v) mapped in the fish-eye image based on the new space coordinate.

10. The device of claim 9, wherein the first conversion unit calculates the incident angel θ and the deviation angle φ based on the coordinates x and y of a point on the blank image used for rectifying the image, the fish-eye lens field angle fov, the width w and height h of the blank image, Formula 3: $\theta = y / A \times \pi$ and Formula 4: $\varphi = (x / w \times fov + (360 - fov) / 2) \times \pi/180$; and calculates the spherical coordinates x_1, y_1, and z_1 based on the angles θ and φ, and using Formula 5: x, = sin(θ)cos (φ), , Formula 6: $y_1 = \sin(\theta)\sin(\varphi)$, and Formula 7: $z_1 = \cos(\theta)$.

11. The device of claim 9, wherein the second conversion unit acquires the space coordinates x', y' and z' based on the converted spherical coordinate x_1, y_1 and z_1 and Formula 8:

$$[x', y', z', 1] = [x_1, y_1, z_1, 1]\begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \\ -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}.$$

12. The device of claim 11, wherein the third conversion unit calculates a converted incident angel θ' and a converted deviation angle φ' based on Formula 9: $\theta' = \mathrm{atan}(\sqrt{x'^2 + y'^2}, z')/\pi \times 180$, Formula 10: cp' = atan (y', x') and the space coordinates x', y', and z';

calculates the radius "radius" based on the angle θ', Formula 1, the lens field angle fov, and Formula 11: *radius* = *R* × *F(0')* / *F(fov* 12); and
and calculates the coordinates u and v mapped in the fish-eye image based on the angle φ', the center coordinates x_0 and y_0 of the fish-eye circle, the radius *'radius',* and Formula 12: $u = radius \times \cos(\varphi') + x_0$, Formula 13: $v = radius \times \sin(\varphi') + y_0$.

13. A computer program product comprising instructions which, when the program is executed by a computer, cause the computer to carry out the method of any of claims 1 to 7.

Patentansprüche

1. Ein Verfahren zum Entzerren eines mit einer Fischaugenlinse aufgenommenen Bildes, **dadurch gekennzeichnet, dass** es die folgenden Schritte umfasst:

   das Erfassen (110) eines Fischaugenlinsen-Abbildungsparameters und eines Linsen-Feldwinkels;
   das Erfassen (120) einer angepassten Abbildungskurve entsprechend dem Linsen-Abbildungsparameter;
   das Erfassen (130) der Mittelpunktskoordinate und des Radius eines Fischaugenkreises in einem Fischaugenbild;
   das Erzeugen (140) eines Leerbildes, das zum Entzerren des Bildes verwendet wird, entsprechend dem Linsen-Feldwinkel;
   auf der Grundlage (150) des Linsen-Feldwinkels, der angepassten Abbildungskurve, der Mittelpunktskoordinate und des Radius des Fischaugenkreises sowie einer Breite und Höhe des Leerbildes, das Abbilden eines Punktes auf dem Leerbild, das zum Entzerren des Bildes verwendet wird, auf einen entsprechenden Punkt in dem Fischaugenbild; und
   basierend (160) auf einem Farbsample des entsprechenden Punktes in dem Fischaugenbild, das Zeichnen desselben auf den korrespondierenden Punkt in dem Leerbild, das für das Entzerren des Bildes verwendet wird, und das Zeichnen des entzerrten Bildes
   dadurch gekennzeichnet, dass in dem Schritt des Erfassens (120) einer angepassten Abbildungskurve gemäß den Linsen-Abbildungsparametern die angepasste Abbildungskurve gemäß der Formel 1 ist:

   $$r_{Real} = F(\theta) = 1{,}0 \times 10^{-9}\,\theta^4 - 6{,}0 \times 10^{-7}\,\theta^3 + 8{,}5 \times 10^{-6}\,\theta^2 + 0{,}01830\theta + 0{,}0007,$$

   wobei θ ein Einfallswinkel ist, r_{Real} ein Abstand zu einem Zentrum eines Films ist, von dem aus das Licht mit dem Einfallswinkel θ nach Brechung durch eine Linse auf dem Film abgebildet wird.

2. Das Verfahren zum Entzerren eines mit einer Fischaugenlinse aufgenommenen Bildes nach Anspruch 1, wobei in dem Schritt des Erfassens (130) der Mittelpunktskoordinate X_0 und Y_0 und des Radius "R" des Fischaugenkreises in einem Fischaugenbild: die Mittelpunktskoordinate X_0 und Y_0 und der Radius 'R' des Fischaugenkreises in einem Fischaugenbild erfasst werden, wobei der Fischaugenkreis der kleinste Kreis ist, der alle Bilder in dem Fischaugenbild enthalten kann.

3. Das Verfahren zum Entzerren eines mit einer Fischaugenlinse aufgenommenen Bildes nach Anspruch 1, wobei in dem Schritt des Erzeugens (140) eines Leerbildes, das zum Entzerren des Bildes verwendet wird, entsprechend dem Linsen-Feldwinkel:
   die Breite w und die Höhe h des LeerBildes entsprechend der Größe des zu entzerrenden Bildes eingestellt werden, und das Seitenverhältnis des Leerbildes gleich fov: 180 ist, wobei fov ein Fischaugenlinsen-Feldwinkel ist.

4. Das Verfahren zum Entzerren eines mit einer Fischaugenlinse aufgenommenen Bildes nach Anspruch 1, wobei der Schritt des, basierend (150) auf dem Linsen-Feldwinkel, der angepassten Abbildungskurve, der Mittelpunktskoordinate und dem Radius des Fischaugenkreises und der Breite und Höhe des Leerbildes, Abbildens eines Punkt auf dem Leerbild, das zum Entzerren des Bildes verwendet wird, auf einen entsprechenden Punkt in dem Fischaugenbild, ferner folgende Schritte umfasst:

   das Umwandeln (5a) einer Koordinate (x, y) eines Punktes auf dem Leerbild, das für das Entzerren des Bildes verwendet wird, in eine Kugelkoordinate (x_1 , y_1 , z_1) auf der Grundlage des Abbildungsverfahrens von Breiten- und Längengraden;
   das Bilden (5b) einer neuen Raumkoordinate (x', y', z') durch Drehen der umgewandelten Kugelkoordinate (x_1, y_1, z_1) um -90 Grad um die Y-Achse der Raumkoordinate; und
   das Erhalten (5c) einer Koordinate (u, v), die auf der Grundlage der neuen Raumkoordinate in dem Fischaugenbild abgebildet wird.

5. Das Verfahren zum Entzerren eines mit einer Fischaugenlinse aufgenommenen Bildes nach Anspruch 4, wobei in dem Schritt des Umwandelns (5a) einer Koordinate (x, y) eines Punktes auf dem Leerbild, das zum Entzerren des Bildes verwendet wird, in eine sphärische Koordinate (x_1, y_1, z_1) auf der Grundlage des Abbildungsverfahrens von Breiten- und Längengraden ein Einfallswinkel θ und ein Abweichungswinkel φ auf der Grundlage der Koordinaten x und y eines Punktes auf dem Leerbild, das zum Entzerren des Bildes verwendet wird, des Fischaugenlinsen-

Feldwinkels fov, der Breite w und der Höhe h des Leerbildes, der Formel 3: $\theta = y / h \times \pi$, und

der

$$\text{Formel 4:} \varphi = (x / w \times fov + (360 - fov) / 2) \times \pi / 180$$

berechnet werden;
die Kugelkoordinate (x_1 , y_1 , z_1) auf der Grundlage des Einfallswinkels θ und des Abweichungswinkels φ, der Formel 5: $x_1 = \sin(\theta) \cos(\varphi)$,
der

$$\text{Formel 6: } y_1 = \sin(\theta) \sin(\varphi),$$

und
der

$$\text{Formel 7: } z_1 = \cos(\theta)$$

berechnet wird.

6. Das Verfahren zum Entzerren eines mit einer Fischaugenlinse aufgenommenen Bildes nach Anspruch 4, wobei, in dem Schritt des Bildens (5b) einer neuen Raumkoordinate (x', y', z') durch Drehen der umgewandelten Kugelkoordinate (x_1 , y_1 , z_1) um -90 Grad um die Y-Achse der Raumkoordinate, die Raumkoordinaten x', y' und z' erhalten werden basierend auf den umgewandelten Kugelkoordinaten x_1, y_1 und z_1 und der Formel 8:

$$[x', y', z', \mathbf{1}] = [x_1, y_\mathbf{1}, z_1, 1] \begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \\ -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}.$$

7. Das Verfahren zum Entzerren eines mit einer Fischaugenlinse aufgenommenen Bildes nach Anspruch 6, wobei in dem Schritt des Erhaltens (5c) einer Koordinate (u, v), die in dem Fischaugenbild auf der Grundlage der neuen Raumkoordinate abgebildet wird, ein umgewandelter Einfallswinkel θ' und ein umgewandelter Abweichungswinkel φ' auf der Grundlage berechnet werden anhand

der

$$\text{Formel 9: } \theta' = \operatorname{atan}\left(\sqrt{x'^2 + y'^2}, z'\right) / \pi \times 180,$$

der

$$\text{Formel 10:} \varphi' = \operatorname{atan}(y', x') \text{ und der Raumkoordinaten } (x', y', z');$$

ein Radius "radius" auf der Grundlage des umgerechneten Einfallswinkels θ', der Formel 1, des Linsen-Feldwinkels fov und der Formel 11 berechnet wird:

$$\text{radius} = R \times F(\theta') / F(fov / 2),$$

die in das Fischaugenbild abgebildeten Koordinaten u und v auf der Grundlage des Winkels φ', der Mittelpunktskoordinaten x_0 und y_0 des Fischaugenkreises, des Radius 'radius', der

$$\text{Formel 12: } u = \text{Radius} \times \cos(\varphi ') + x_0 ,$$

und
der

$$\text{Formel 13: } v = \text{Radius} \times \sin(\varphi ') + y_0$$

berechnet werden.

8. Eine Vorrichtung zum Entzerren eines mit einer Fischaugenlinse aufgenommenen Bildes, umfassend:

eine erste Datenerfassungseinheit, die zum Erfassen eines Fischaugenlinsen-Abbildungsparameters und eines Linsen-Feldwinkels verwendet wird;
eine Abbildungskurven-Anpassungseinheit, die zum Erfassen einer angepassten Abbildungskurve gemäß dem Linsen-Abbildungsparameter verwendet wird;
eine zweite Datenerfassungseinheit, die zur Erfassung der Mittelpunktskoordinate und des Radius eines Fischaugenkreises in einem Fischaugenbild dient;
eine Leerbild-Erzeugungseinheit, die zur Erzeugung eines Leerbildes dient, das zum Entzerren des Bildes verwendet wird, entsprechend dem Linsen-Feldwinkel;
eine Abbildungseinheit, die verwendet wird, um auf der Grundlage des Linsen-Feldwinkels, der angepassten Abbildungskurve, der Mittelpunktskoordinate und des Radius des Fischaugenkreises und einer Breite und Höhe des Leerbildes einen Punkt auf dem Leerbild, der zum Entzerren des Bildes verwendet wird, auf einen entsprechenden Punkt in dem Fischaugenbild abzubilden; und
eine Zeichnungseinheit, die dazu dient, auf der Grundlage eines Farbsamples des entsprechenden Punktes in dem Fischaugenbild, jenen auf den entsprechenden Punkt in dem Leerbild, das zum Entzerren des Bildes verwendet wird, zu zeichnen;
dadurch gekennzeichnet, dass die angepasste Abbildungskurve gemäß den Linsen-Abbildungsparametern anhand der Formel 1 erfasst wird:

$$r_{Real} = F(\theta) = 1{,}0 \times 10^{-9}\, \theta^4 - 6{,}0 \times 10^{-7}\, \theta^3 + 8{,}5 \times 10^{-6}\, \theta^2 + 0{,}01830 + 0{,}0007,$$

wobei θ ein Einfallswinkel ist, r_{Real} ein Abstand zu einem Zentrum eines Films ist, von dem aus das Licht mit dem Einfallswinkel θ nach Brechung durch eine Linse auf dem Film abgebildet wird;
die Mittelpunktskoordinaten X_0 und Y_0 und der Radius 'R' des Fischaugenkreises in einem Fischaugenbild erfasst werden, wobei der Fischaugenkreis der kleinste Kreis ist, der alle Bilder in dem Fischaugenbild enthalten kann;
die Breite w und die Höhe h des Leerbildes entsprechend der Größe des zu entzerrenden Bildes eingestellt werden, und das Seitenverhältnis des Leerbildes gleich fov: 180 ist, wobei fov der Bildwinkel einer Fischaugenlinse ist.

9. Die Vorrichtung nach Anspruch 8, wobei eine Abbildungsseinheit folgende Einheiten umfasst:

eine erste Konvertierungseinheit, die zum Konvertieren einer Koordinate (x, y) eines Punktes auf dem Leerbild, das zum Entzerren des Bildes verwendet wird, in eine Kugelkoordinate (x_1, y_1, z_1) auf der Grundlage des Abbildungsverfahrens von Breiten- und Längengraden verwendet wird;
eine zweite Konvertierungseinheit, die zur Bildung einer neuen Raumkoordinate (x', y', z') durch Drehen der umgewandelten Kugelkoordinate (x_1, y_1, z_1) um -90 Grad um die Y-Achse der Raumkoordinate verwendet wird; und
eine dritte Konvertierungseinheit, die dazu dient, eine in das Fischaugenbild abgebildete Koordinate (u, v) auf der Grundlage der neuen Raumkoordinate zu erhalten.

10. Die Vorrichtung nach Anspruch 9, **dadurch gekennzeichnet, dass** die erste Konvertierungseinheit den Einfallswinkel θ und den Abweichungswinkel φ auf der Grundlage der Koordinaten x und y eines Punktes auf dem Leerbild, das für das Entzerren des Bildes verwendet wird, des Fischaugenlinsen-Feldwinkels fov, der Breite w und der Höhe h des Leerbildes, der Formel 3: $\theta = y / h \times \pi$, und der Formel 4:$\varphi = (x / w \times fov + (360 - fov) / 2) \times \pi / 180$ berechnet; und die Kugelkoordinaten x_1 , y_1 und z_1 auf der Grundlage der Winkel θ und φ und unter Verwendung von Formel 5: $x_1 = \sin(\theta) \cos(\varphi)$, Formel 6: $y_1 = \sin(\theta) \sin(\varphi)$, und Formel 7: $z_1 = \cos(\theta)$ berechnet.

11. Die Vorrichtung nach Anspruch 9, wobei die zweite Abbildungseinheit die Raumkoordinaten x', y' und z' basierend auf den umgewandelten Kugelkoordinaten x_1 , y_1 und z_1 und der Formel 8 ermittelt:

$$[x',y',z',\mathbf{1}] = [x_1,y_1,z_1,1]\begin{bmatrix}0 & 0 & 1 & 0\\0 & 1 & 0 & 0\\-1 & 0 & 0 & 0\\0 & 0 & 0 & 1\end{bmatrix}.$$

12. Die Vorrichtung nach Anspruch 11, wobei die dritte Konvertierungseinheit einen umgewandelten Einfallswinkel θ' und einen umgewandelten Ablenkungswinkel φ' berechnet, basierend auf Formel 9: $\theta' = \mathrm{atan}\,(\sqrt{x'^2 + y'^2}, z') / \pi \times 180$, Formel 10:$\varphi' = \mathrm{atan}(y', x')$ und die Raumkoordinaten x', y' und z';

den Radius 'radius' auf der Grundlage des Winkels θ', der Formel 1, des Linsen-Feldwinkels fov und der Formel 11: radius = $R \times F(\theta') / F(fov / 2)$ berechnet; und
die in das Fischaugenbild abgebildeten Koordinaten u und v anhand des Winkels φ', der Mittelpunktskoordinaten x_0 und y_0 des Fischaugenkreises, des Radius 'radius' und der Formel 12: u = radius $\times \cos(\varphi') + x_0$, Formel 13: v = radius $\times$ sin(cp ') + y_0 berechnet.

13. Ein Computerprogrammprodukt mit Anweisungen, die, wenn das Programm von einem Computer ausgeführt wird, den Computer veranlassen, das Verfahren nach einem der Ansprüche 1 bis 7 auszuführen.

Revendications

1. Procédé de rectification d'une image photographiée par un objectif fish-eye, comprenant les étapes suivantes :

l'acquisition (110) d'un paramètre de mappage d'objectif fish-eye et d'un angle de couverture ;
l'acquisition (120), en fonction du paramètre de mappage d'objectif, d'une courbe de mappage ajustée ;
l'acquisition (130) de coordonnées centrales et du rayon d'un cercle fish-eye dans une image fish-eye ;
la création (140) d'une image vierge servant à rectifier l'image en fonction de l'angle de couverture ;
en fonction (150) de l'angle de couverture, de la courbe de mappage ajustée, des coordonnées centrales et du rayon de cercle fish-eye, ainsi que de la largeur et de la hauteur de l'image vierge, le mappage d'un point sur l'image vierge servant à rectifier l'image eu égard à un point correspondant dans l'image fish-eye ; et
en fonction (160) d'un échantillon de couleur du point correspondant dans l'image fish-eye, son traçage sur le point correspondant dans l'image vierge servant à rectifier l'image, et le traçage de l'image rectifiée ;
caractérisé en ce que, lors de l'étape d'acquisition (120), selon les paramètres de mappage d'objectif, d'une courbe de mappage ajustée, la courbe de mappage ajustée correspond à la formule 1 :

$$r_{Real} = F(\theta) = 1{,}0 \times 10^{-9}\theta^4 - 6{,}0 \times 10^{-7}\theta^3 + 8{,}5 \times 10^{-6}\theta^2 + 0{,}0183\theta + 0{,}0007$$

dans laquelle θ est l'angle d'incidence, r_{Real} est la distance par rapport au centre d'un film à partir duquel la lumière à l'angle d'incidence θ est mappée sur le film après avoir été réfractée à travers un objectif.

2. Procédé de rectification d'une image photographiée par un objectif fish-eye selon la revendication 1,
dans lequel, lors de l'étape d'acquisition (130) des coordonnées centrales et du rayon d'un cercle fish-eye dans une image fish-eye : les coordonnées centrales X_0 et Y_0 et le rayon R du cercle fish-eye dans une image fish-eye sont acquis, le cercle fish-eye étant le plus petit cercle capable de contenir toutes les images dans l'image fish-eye.

3. Procédé de rectification d'une image photographiée par un objectif fish-eye selon la revendication 1, dans lequel, lors de l'étape de création (140) d'une image vierge servant à rectifier l'image en fonction de l'angle de couverture : la largeur w et la hauteur h de l'image vierge sont définies en fonction de la taille de l'image à rectifier, et le rapport d'aspect de l'image vierge est égal à fov : 180, où fov est l'angle de couverture fish-eye.

4. Procédé de rectification d'une image photographiée par un objectif fish-eye selon la revendication 1, dans lequel l'étape consistant à, en fonction (150) de l'angle de couverture, de la courbe de mappage ajustée, des coordonnées centrales et du rayon de cercle fish-eye, ainsi que de la largeur et la hauteur de l'image vierge, mapper un point sur l'image vierge servant à rectifier l'image à un point correspondant dans l'image fish-eye, comprend en outre les étapes suivantes :

la conversion (5a) des coordonnées (x, y) d'un point sur l'image vierge servant à rectifier l'image en coordonnées sphériques (x_1, y_1, z_1) en fonction du procédé de mappage de la latitude et de la longitude ;
la formation (5b) de nouvelles coordonnées spatiales (x', y', z') par rotation des coordonnées sphériques converties (x_1, y_1, z_1) de -90 degrés autour de l'axe Y des coordonnées spatiales ; et
l'obtention (5c) de coordonnées (u, v) mappées dans l'image fish-eye en fonction des nouvelles coordonnées spatiales.

5. Procédé de rectification d'une image photographiée par un objectif fish-eye selon la revendication 4, dans lequel, lors de l'étape de conversion (5a) des coordonnées (x, y) d'un point sur l'image vierge servant à rectifier l'image en coordonnées sphériques (x_1, y_1, z_1) en fonction du procédé de mappage de la latitude et de la longitude, l'angle d'incidence θ et un angle de déviation φ sont calculés en fonction des coordonnées x et y d'un point sur l'image vierge servant à rectifier l'image, de l'angle de champ fov de l'objectif fish-eye, de la largeur w et de la hauteur h de l'image vierge, de la formule 3 : $\theta = y/h \times \pi$ et de la formule 4 :

$$\varphi = (x/w \times fov + (360 - fov)/2) \times \pi/180 ;$$

les coordonnées sphériques (x_1, y_1, z_1) sont calculées en fonction de l'angle d'incidence θ, de l'angle de déviation φ, de la formule 5 : $x_1 = \sin(\theta)\cos(\varphi)$, de la formule 6 : $y_1 = \sin(\theta)\sin(\varphi)$ et de la formule 7 : $z_1 = \cos(\theta)$.

6. Procédé de rectification d'une image photographiée par un objectif fish-eye selon la revendication 4, dans lequel, lors de l'étape de formation (5b) de nouvelles coordonnées spatiales (x', y', z') par rotation des coordonnées sphériques converties (x_1, y_1, z_1) de -90 degrés autour de l'axe Y des coordonnées spatiales, les coordonnées spatiales x', y' et z' sont obtenues en fonction des coordonnées sphériques converties x_1, y_1 et z_1 et de la formule 8 :

$$[x', y', z', 1] = [x_1, y_1, z_1, 1]\begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \\ -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}.$$

7. Procédé de rectification d'une image photographiée par un objectif fish-eye selon la revendication 6, dans lequel, lors de l'étape d'obtention (5c) de coordonnées (u, v) mappées dans l'image fish-eye en fonction des nouvelles coordonnées spatiales, un angle d'incidence converti θ' et un angle de déviation converti φ' sont calculés en fonction de la formule 9 la formule 9 : $\theta' = \mathrm{atan}(\sqrt{x'^2 + y'^2}, z')/\pi \times 180$, de la formule 10 : $\varphi' = \mathrm{atan}(y', x')$ et des coordonnées spatiales (x', y', z') ;

un rayon « *radius* » est calculé en fonction de l'angle d'incidence converti θ', de la formule 1, de l'angle de couverture fov et de la formule 11 : $radius = R \times F(\theta')/F(fov/2)$;
les coordonnées u et v mappées dans l'image fish-eye sont calculées en fonction de l'angle φ', des coordonnées centrales x_0 et y_0 du cercle fish-eye, du rayon « *radius* », de la formule 12 : $u = radius \times \cos(cp') + x_0$ et de la formule 13 : $v = radius \times \sin(cp') + y_0$.

8. Dispositif de rectification d'une image photographiée par un objectif fish-eye, comprenant :

une première unité d'acquisition de données, servant à acquérir un paramètre de mappage d'objectif fish-eye et un angle de couverture ;

une unité d'ajustement de courbe de mappage, servant à acquérir une courbe de mappage ajustée en fonction du paramètre de mappage d'objectif ;

une deuxième unité d'acquisition de données, servant à acquérir des coordonnées centrales et un rayon d'un cercle fish-eye dans une image fish-eye ;

une unité de création d'image vierge, servant à créer une image vierge servant à rectifier l'image en fonction de l'angle de couverture ;

une unité de mappage, servant à, en fonction de l'angle de couverture, de la courbe de mappage ajustée, des coordonnées centrales et du rayon de cercle fish-eye, ainsi que de la largeur et la hauteur de l'image vierge, mapper un point sur l'image vierge servant à rectifier l'image eu égard à un point correspondant dans l'image fish-eye ; et

une unité de traçage, servant à, en fonction d'un échantillon de couleur du point correspondant dans l'image fish-eye, effectuer son traçage sur le point correspondant dans l'image vierge servant à rectifier l'image, et tracer l'image rectifiée ;

caractérisé en ce que la courbe de mappage ajustée est acquise en fonction des paramètres de mappage d'objectif selon la formule 1 :

$$r_{Real} = F(\theta) = 1{,}0 \times 10^{-9}\theta^4 - 6{,}0 \times 10^{-7}\theta^3 + 8{,}5 \times 10^{-6}\theta^2 + 0{,}0183\theta + 0{,}0007$$

dans laquelle θ est l'angle d'incidence, r_{Real} est la distance par rapport au centre d'un film à partir duquel la lumière à l'angle d'incidence θ est mappée sur le film après avoir été réfractée à travers un objectif ;

les coordonnées centrales X_0 et Y_0 et le rayon R du cercle fish-eye dans une image fish-eye sont acquis, le cercle fish-eye étant le plus petit cercle capable de contenir toutes les images dans l'image fish-eye ;

la largeur w et la hauteur h de l'image vierge sont définies en fonction de la taille de l'image à rectifier, et le rapport d'aspect de l'image vierge est égal à fov : 180, où fov est l'angle de couverture fish-eye.

9. Dispositif selon la revendication 8, dans lequel une unité de mappage comprend des unités de :

une première unité de conversion, servant à convertir des coordonnées (x, y) d'un point sur l'image vierge servant à rectifier l'image en coordonnées sphériques (x_1, y_1, z_1) en fonction du procédé de mappage de la latitude et de la longitude ;

une deuxième unité de conversion, servant à former de nouvelles coordonnées spatiales (x', y', z') par rotation des coordonnées sphériques converties (x_1, y_1, z_1) de -90 degrés autour de l'axe Y des coordonnées spatiales ; et

une troisième unité de conversion, servant à obtenir des coordonnées (u, v) mappées dans l'image fish-eye en fonction des nouvelles coordonnées spatiales.

10. Dispositif selon la revendication 9, dans lequel la première unité de conversion calcule l'ange d'incidence θ et l'angle de déviation φ en fonction des coordonnées x et y d'un point sur l'image vierge servant à rectifier l'image, de l'angle de couverture fish-eye fov, de la largeur w et de la hauteur h de l'image vierge, de la formule 3 : $\theta = y/h \times \pi$ et de la formule 4 : $\varphi = (x/w \times fov + (360 - fov)/2) \times \pi/180$; et calcule les coordonnées sphériques x_1, y_1 et z_1 en fonction des angles θ et φ, et à l'aide de la formule 5 : $x_1 = \sin(\theta)\cos(\varphi)$, de la formule 6 : $y_1 = \sin(\theta)\sin(\varphi)$ et de la formule 7 : $z_1 = \cos(\theta)$.

11. Dispositif selon la revendication 9, dans lequel la deuxième unité de conversion acquiert les coordonnées spatiales x', y' et z' en fonction des coordonnées sphériques converties x_1, y_1 et z_1 et de la formule 8 :

$$[x', y', z', 1] = [x_1, y_1, z_1, 1]\begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 \\ -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

12. Dispositif selon la revendication 11, dans lequel la troisième unité de conversion calcule un angle d'incidence converti θ' et un angle de déviation converti φ' en fonction de la formule 9 : $\theta' = \text{atan}(\sqrt{x'^2 + y'^2}, z')/\pi \times 180$, de la formule 10 : $\varphi' = \text{atan}(y', x')$ et des coordonnées spatiales x', y', et z' ;

elle calcule un rayon « *radius* » en fonction de l'angle d'incidence converti θ', de la formule 1, de l'angle de couverture fov et de la formule 11 : $radius = R \times F(0')/F(fov/2)$;
et
elle calcule les coordonnées u et v mappées dans l'image fish-eye en fonction de l'angle φ', des coordonnées centrales x_0 et y_0 du cercle fish-eye, du rayon « *radius* », de la formule 12 : $u = radius \times \cos(cp') + x_0$ et de la formule 13 : $v = radius \times \sin(cp') + y_0$.

13. Produit programme informatique comprenant des instructions qui, lorsque le programme est exécuté par un ordinateur, amènent l'ordinateur à mettre en oeuvre le procédé selon l'une quelconque des revendications 1 à 7.

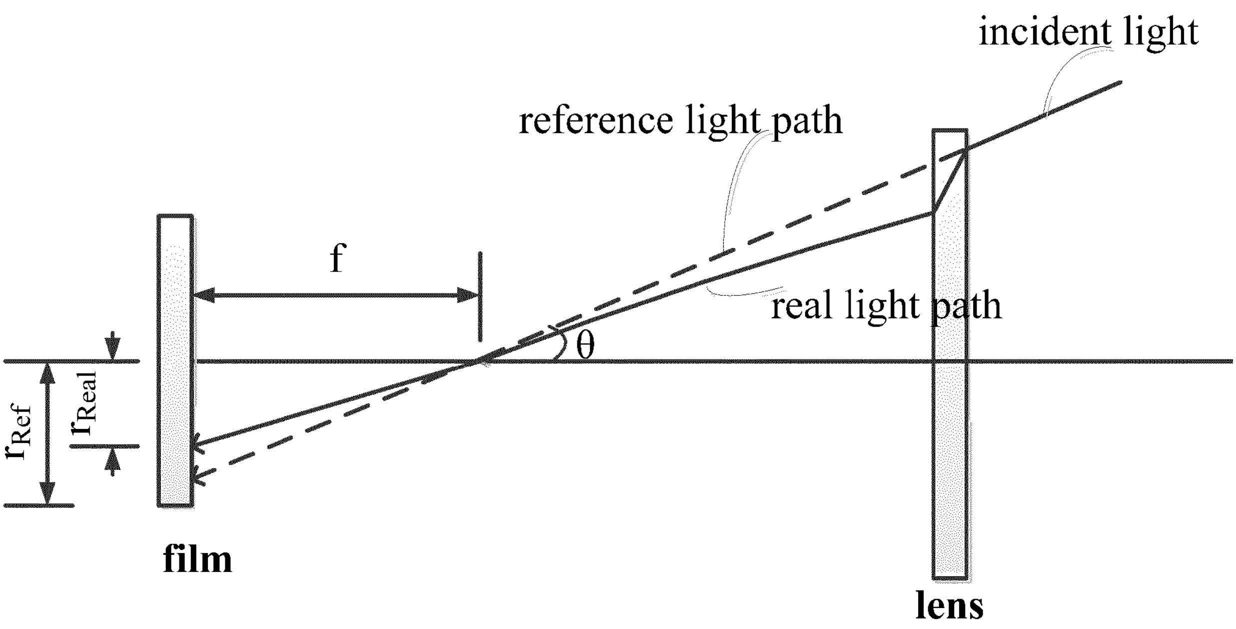
incident light
reference light path
f
real light path
θ
r_{Ref}
r_{Real}
film
lens

FIG. 1

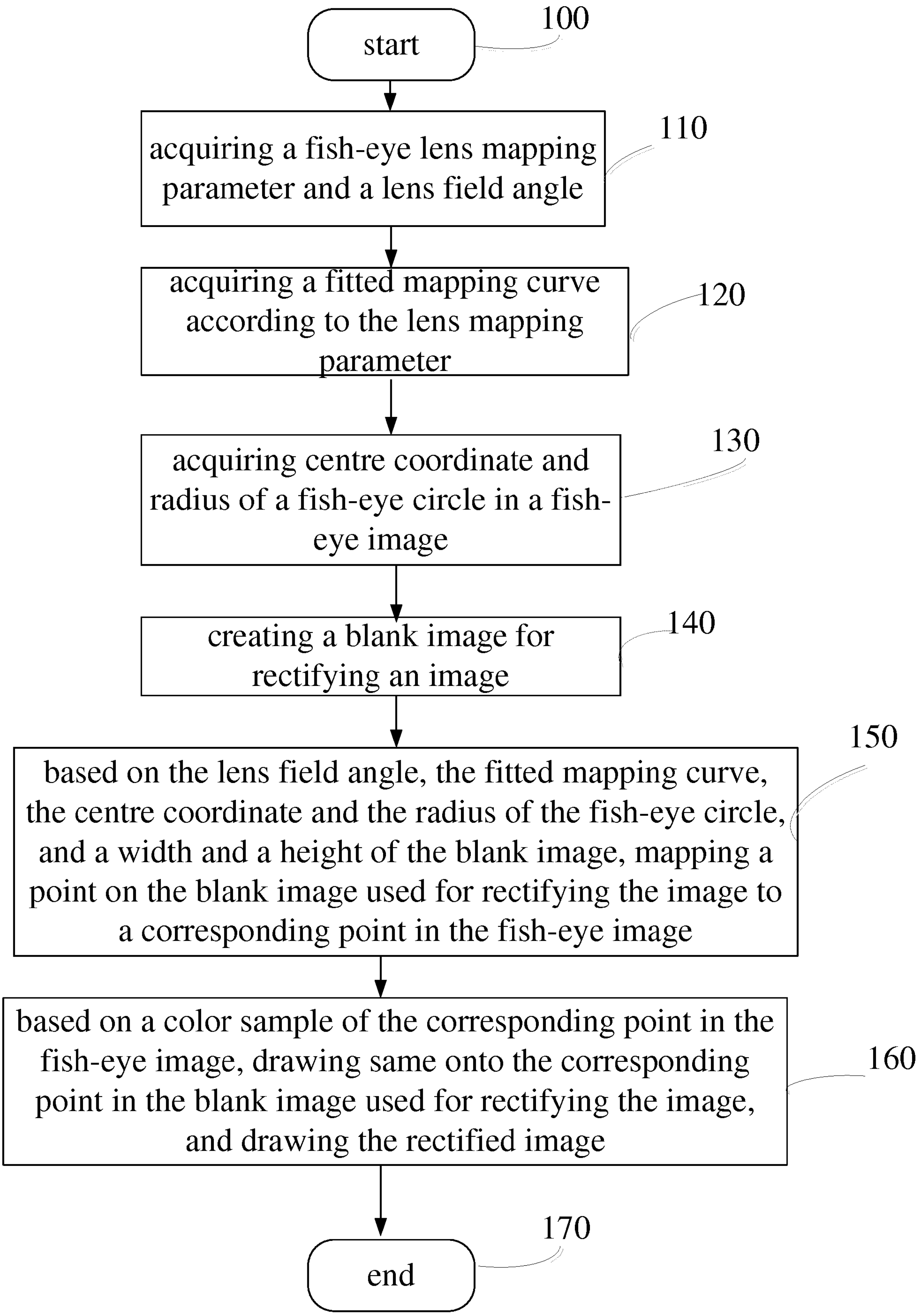
start
100
acquiring a fish-eye lens mapping parameter and a lens field angle
110
acquiring a fitted mapping curve according to the lens mapping parameter
120
acquiring centre coordinate and radius of a fish-eye circle in a fish-eye image
130
creating a blank image for rectifying an image
140
based on the lens field angle, the fitted mapping curve, the centre coordinate and the radius of the fish-eye circle, and a width and a height of the blank image, mapping a point on the blank image used for rectifying the image to a corresponding point in the fish-eye image
150
based on a color sample of the corresponding point in the fish-eye image, drawing same onto the corresponding point in the blank image used for rectifying the image, and drawing the rectified image
160
end
170

FIG. 2

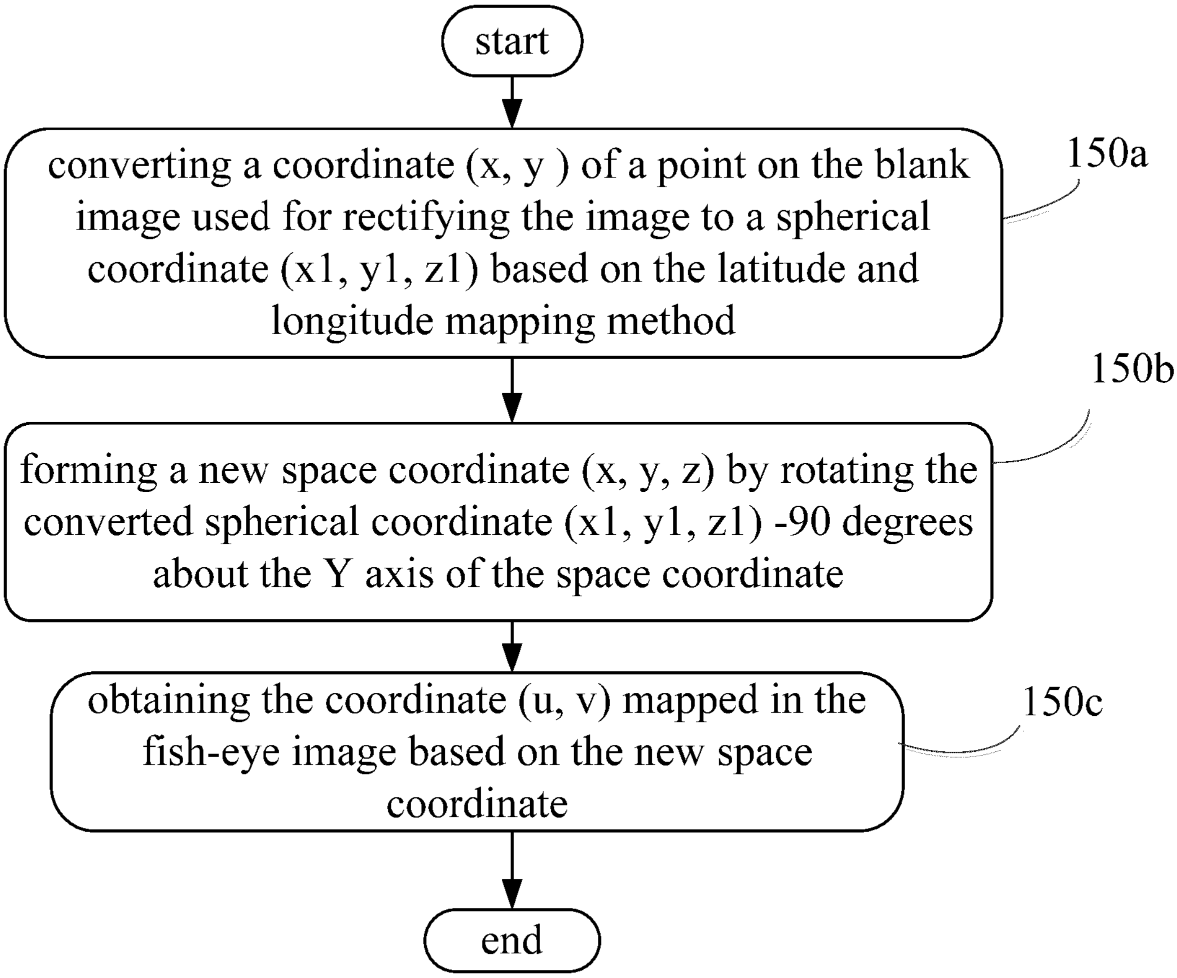
start
converting a coordinate (x, y) of a point on the blank image used for rectifying the image to a spherical coordinate (x1, y1, z1) based on the latitude and longitude mapping method
150a
forming a new space coordinate (x, y, z) by rotating the converted spherical coordinate (x1, y1, z1) -90 degrees about the Y axis of the space coordinate
150b
obtaining the coordinate (u, v) mapped in the fish-eye image based on the new space coordinate
150c
end

FIG. 3

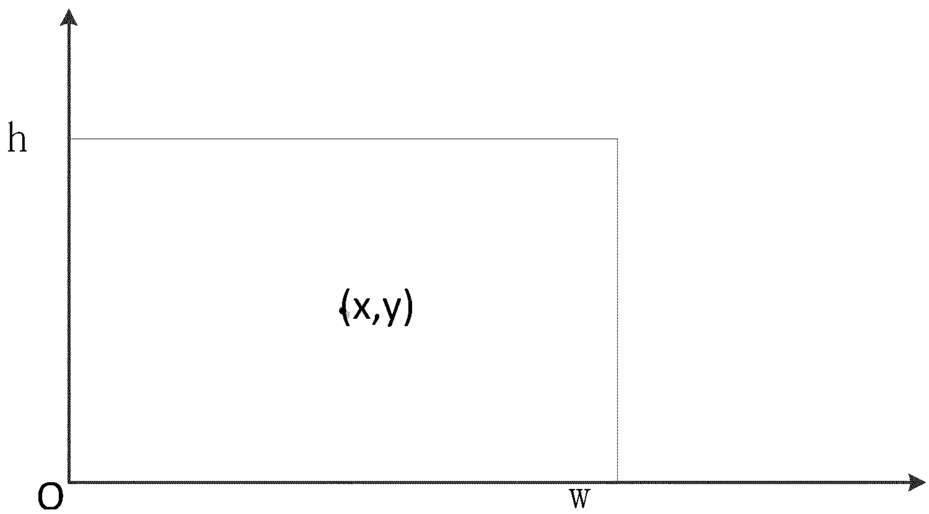
h
(x,y)
O
w

FIG. 4

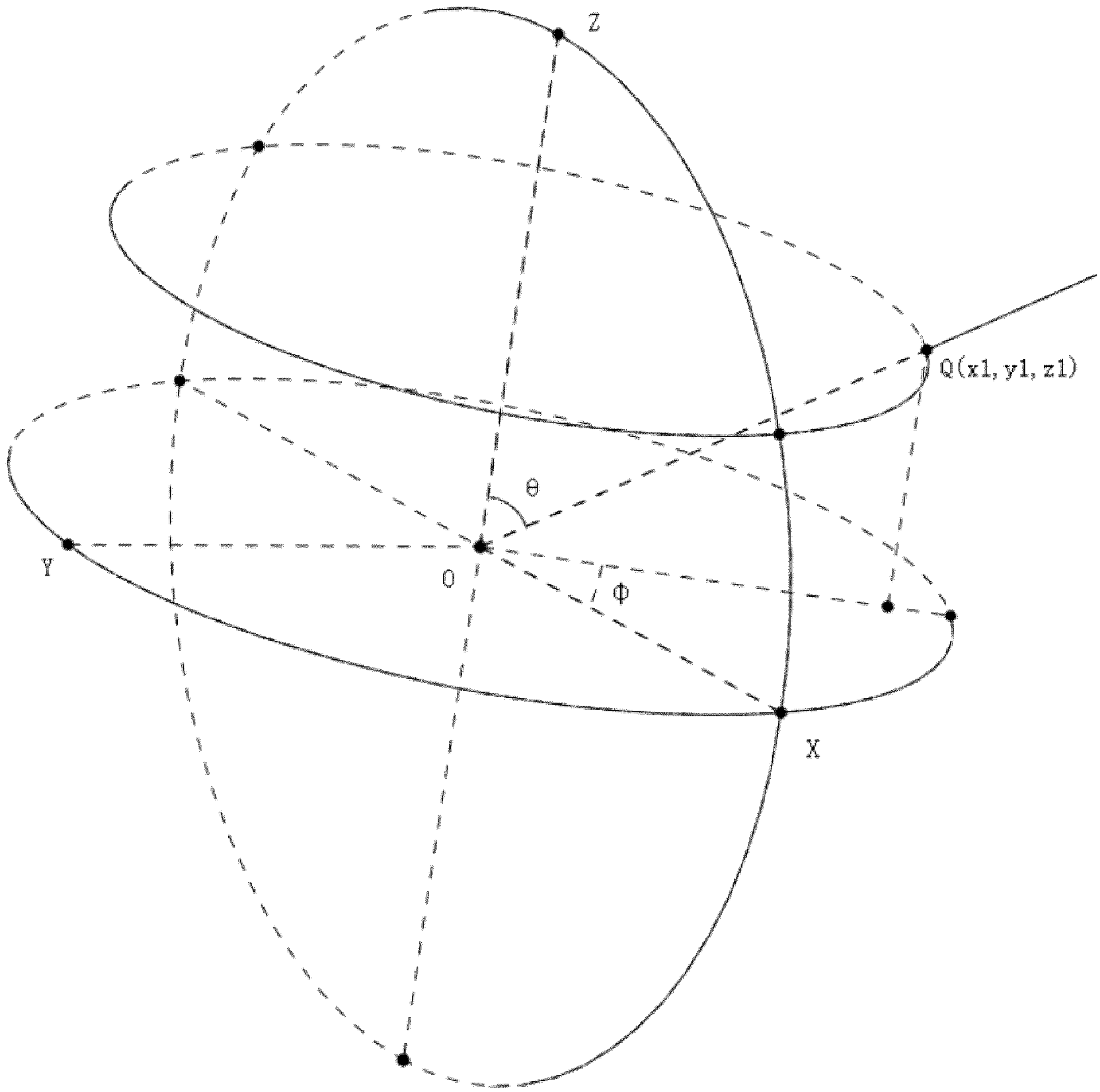

FIG. 5

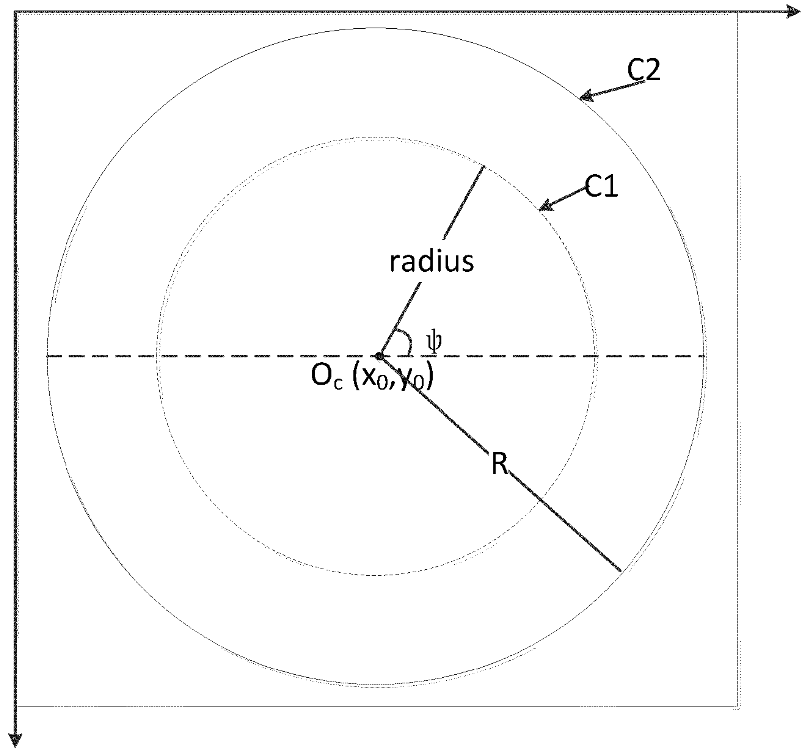
C2
C1
radius
ψ
O_c (x_0, y_0)
R

FIG. 6

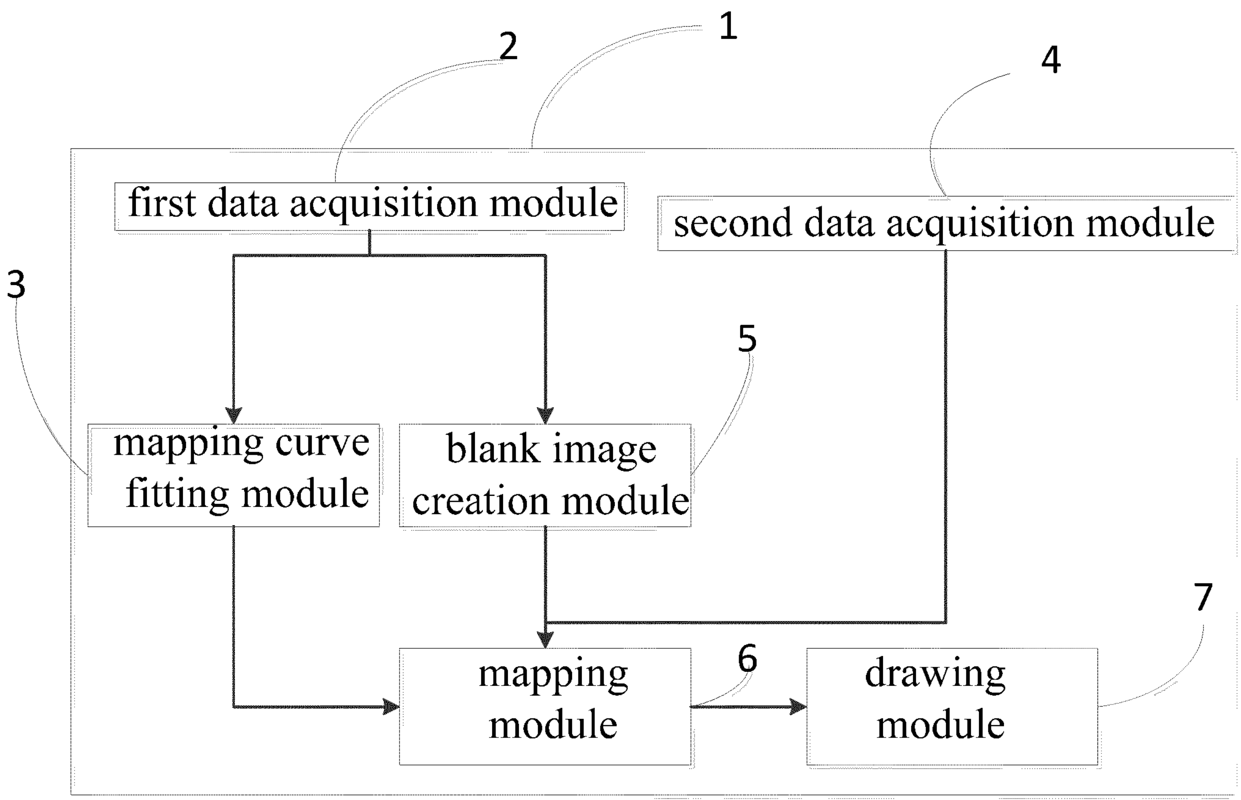
1
2
4
3
5
7
6
first data acquisition module
second data acquisition module
mapping curve fitting module
blank image creation module
mapping module
drawing module

FIG. 7

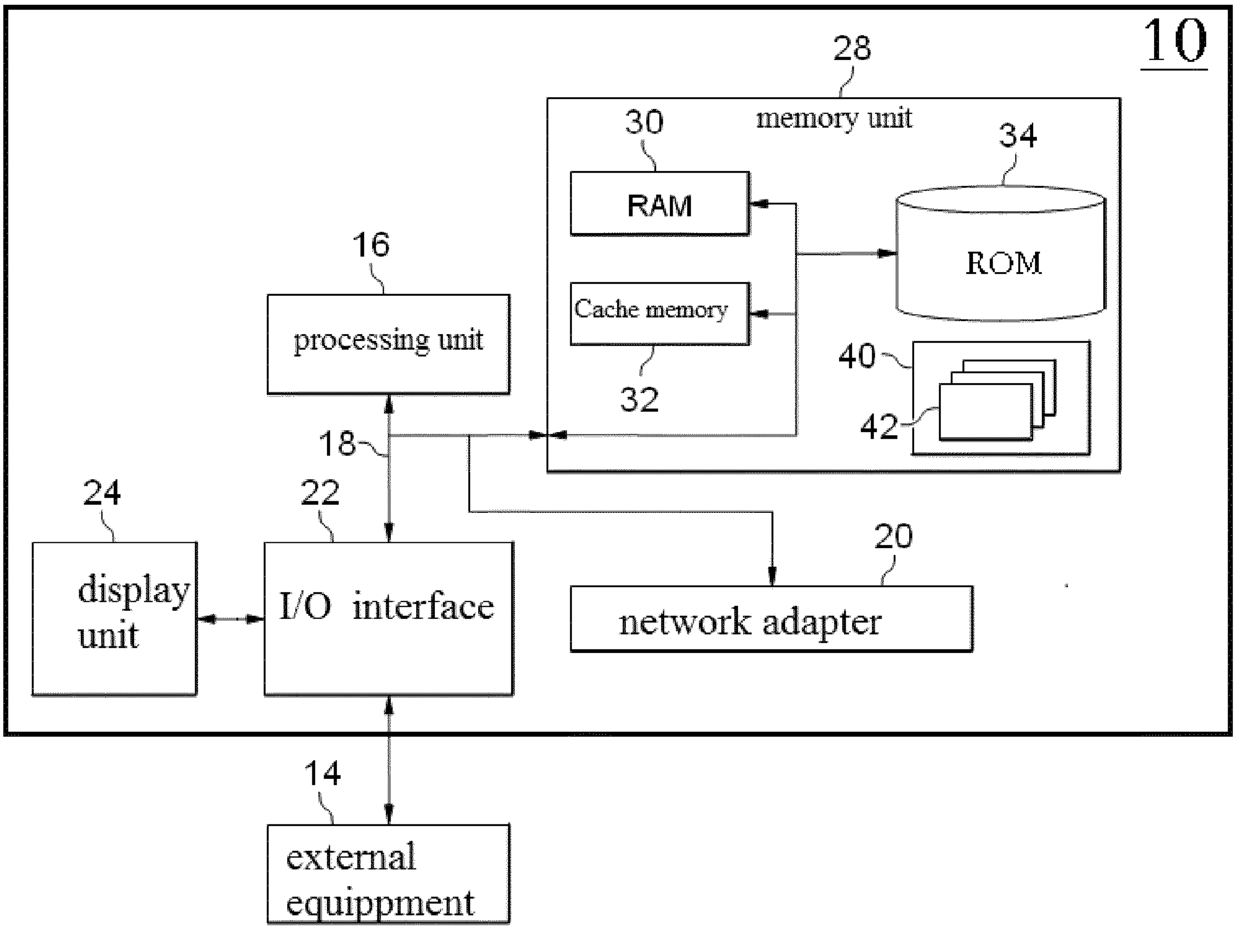
10
28
memory unit
30
RAM
34
ROM
16
processing unit
Cache memory
32
40
42
18
24
22
20
display unit
I/O interface
network adapter
14
external equippment

FIG.8

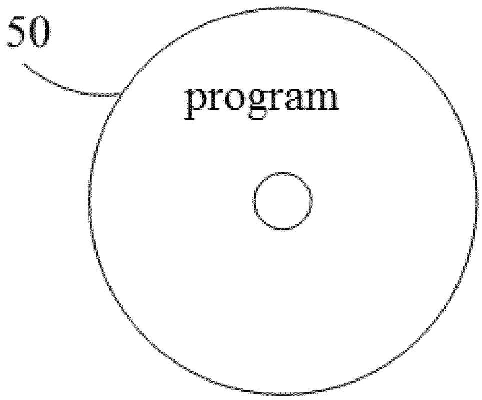
50
program

FIG.9

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 8482595 B2 **[0006]**

Non-patent literature cited in the description

- **PRANALI DHANE et al.** A Generic Non-linear Method for Fisheye Correction. *International Journal of Computer Applications,* 01 August 2012, vol. 51 (10), 58-65 **[0006]**